GEOLOGIC HISTORY OF PAINTHORSE QUADRANGLE,

CULBERSON COUNTY, TEXAS

by

George Sealy, Jr.

Presented to the Facu[redacted]

The University of T[redacted]

of th[redacted]

For the Degree of

MASTER OF ARTS

[redacted]

THE UNIVERSITY OF TEXAS
AUGUST, 1952

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THESIS

Presented to the Faculty of the Graduate School of

The University of Texas in Partial Fulfillment

of the Requirements

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ABSTRACT

The Painthorse quadrangle was an area of deposition during every geologic period except the Triassic, Jurassic and Tertiary. Prior to Permian time the area was situated on an unstable shelf which, from time to time, was covered by shallow epicontinental seas. The orogeny at the end of Pennsylvanian time marked the area's transition from a shelf-type depositional region to an intracratonic basin which received great thicknesses of Permian sediments. The area was exposed during the first two periods of the Mesozoic era. The Cretaceous sea moving up from the south marked the last marine transgression. Late Tertiary uplifts accompanied by faulting preceded the deposition of Quaternary alluvium.

CONTENTS

ILLUSTRATIONS

INTRODUCTION

This thesis represents an attempt to interpret the geologic history of a small area by using data gathered from the field and from the literature on adjacent areas. The area mapped is a 7 1/2-minute quadrangle covering approximately 65 square miles near the middle of Culberson County bounded by the meridians $104^{\circ}22'30''$ W and $104^{\circ}30'$ W and the parallels $31^{\circ}22'30''$ N and $31^{\circ}30'$ N.

Structurally the Painthorse quadrangle is situated close to the western edge of the Delaware Basin on a gently eastward dipping homocline of Permian rocks. The surface exposures within the quadrangle represent rocks of middle Guadalupian age and younger. The geologic history from the Guadalupian to the Recent is therefore more completely presented. In the interpretation of older history the writer has been dependent on the meager information available from three nearby wells. In addition he has relied rather heavily on the publications of previous authors who have had an opportunity to study pre-Permian rocks both on the surface and in the subsurface of adjacent areas.

PREVIOUS WORK

Previous geologic work in the area includes G. B. Richardson's (1904) reconnaissance map of northern Trans-Pecos Texas and P. B. King's (1949) regional map of parts of

Culberson and Hudspeth counties, Texas. Parts of the area have been under lease by various oil companies for years and three dry holes have been drilled in search of oil. Numerous shot-holes provide evidence of past seismic exploration in the quadrangle.

The information that the Continental Oil Company plans to send a geophysical team into the area during the summer of 1952 indicates that the oil possibilities are still being explored.

PROCEDURE

The mapping of Painthorse quadrangle was completed in the summer of 1951 by the writer and A. L. Blankenship, Jr. Mapping was accomplished using an Edgar Tobin Aerial Survey controlled mosaic as the base map. This photo, having a scale of 1 inch equals 2,000 feet, precisely covered Painthorse quadrangle. Continental Oil Company made available a set of overlapping air photos (stereo-pairs) of a slightly larger scale (1 inch equals 1,650 feet). With the aid of a large stereoscope, the relief was quite easy to discern and the speed of mapping was greatly increased. In addition, the only instruments used were the Brunton compass and steel tape.

ACKNOWLEDGMENTS

The writer is indebted to Mr. A. L. Blankenship, Jr., for his cooperation in the field and for his service in the preparation of the maps used in this report.

Indebtedness is also acknowledged to Professors R. K. DeFord and J. A. Wilson for their supervision in the field and for Professor DeFord's continued supervision of the preparation of this thesis. Professors S. P. Ellison and J. L. Wilson aided the writer immeasurably by making the necessary identification of fossils and by giving advice and criticism in the final preparations of this paper.

The writer wishes to thank the many landowners who were very cooperative in giving permission to enter their lands and especially Mr. K. P. Looney for providing living quarters on his ranch.

P H Y S I O G R A P H Y

TOPOGRAPHY

Painthorse quadrangle may be divided into approximately two equal parts by a northeast-southwest line representing the Guadalupe-Ochoa contact. East of this line exists karst topography, controlled by the highly soluble Castile gypsum. Near this contact the top of the Bell Canyon is predominately limestone and sufficiently resistant to form a well-defined scarp. At several localities the gypsum of the Castile has been replaced by limestone and forms resistant domes called "castiles" (Adams, 1944, p. 1606). To the southeast, outliers of the Rustler formation, composed of very resistant dolomite and siltstone, cap the Castile formation and form the western edge of the Rustler Hills. These hills are the highest topographic features in the area. Within the area of outcrop of the Castile formation there are many minor cuestas a few feet high capped by thin petroliferous limestone layers. One large limestone bed of this type, roughly 7 feet thick, creates a fairly impressive scarp in Sec. 24, Blk. 97, PSL (Pl. I).

West of the Guadalupe-Ochoa contact the formations of the Delaware Mountain group are composed of fine-grained sandstone and dark limestone. The beds of limestone, being more resistant in this semiarid climate, form the cuestas that are of such great aid to the geologist in mapping from air photos. The Bell Canyon formation is practically completely covered by Quaternary alluvium and gravel terraces. These gravel deposits form the dark gray elongate mounds that cover so much of the area drained by Painthorse Draw.

The topographic relief within the quadrangle does not exceed 350 feet.

The Painthorse area consists of Permian strata that rise to the west, topographically as well as structurally, to form the dip slope of the Delaware Mountains a few miles away.

DRAINAGE

The main artery of drainage is Cottonwood Draw which drains eastward toward the Pecos River. In its course across the northern part of the quadrangle it is fed by three tributary drainage systems. Painthorse Draw on the west receives virtually all the flow west of the Castile-Delaware Mountain contact and empties into Cottonwood Draw northeast of Painthorse dam. The other two minor systems, running parallel to Painthorse Draw, are east of the Castile-Delaware Mountain contact and receive the drainage from that area. These two draws, one called Miller Draw and the other unnamed, traverse the outcrop of the Castile gypsum. The highly soluble and porous nature of this formation accounts for the fact that little water will be found in these channels even immediately after a rain. It is impossible to trap the flow of water because it will seep under any earthen dam constructed in the channel and enter the subsurface drainage systems. What little water is found on the surface is due to clay deposition on the channel bottom.

In the summer of 1951 there were a few stagnant pools of water along Cottonwood Draw but these were rapidly disappearing because of the severe drought over most of Texas.

Many earthen dams were constructed across the channels feeding into Painthorse Draw to trap the water that flowed eastward down the slopes of the Delaware Mountains during those rare rainfalls. These artificial tanks provide virtually all the "sweet" water in the area. Almost any well will encounter "gyp" water and the sheep and cattle seem to adapt themselves to it readily.

S T R A T I G R A P H Y

The rock sequence exposed in Painthorse quadrangle consists of upper Permian rocks of the Delaware-Basin type, Cretaceous rocks of the Fredericksburg (?) and Washita groups, and Pleistocene alluvial deposits.

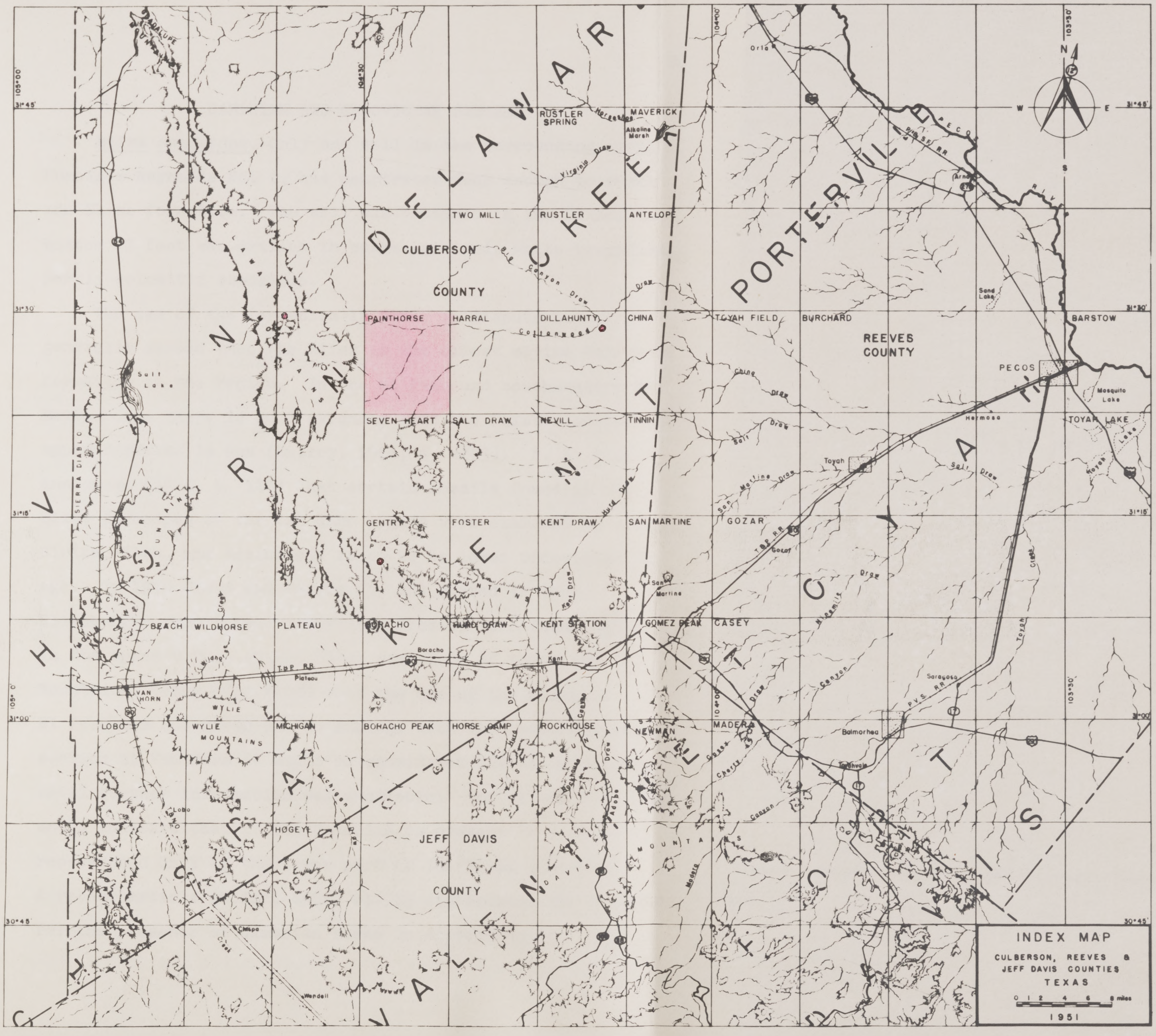
The subsurface data were secured from the following three wells (see Pl. II):

1. Gulf Oil Corporation's M. A. Grisham No. 1, 2,041 feet from the north line and 1,858 feet from the west line of Sec. 18, Blk. 99, Public School Lands, Culberson County, Texas (6 miles west of the west boundary of Painthorse quadrangle). Ground elevation: 5,696 feet. Total depth: 6,000 feet.

2. Gulf and Grisham-Hunter's Grisham-Hunter "F" No. 1, 1,834 feet from the north line and 1,980 feet from the east line of Sec. 16, Blk. 54, Public School Lands, Culberson County, Texas (10 miles east of the east boundary of the area). Derrick floor elevation: 3,597 feet. Total depth: 12,103 feet.

3. Humble Oil and Refining Company's Reynolds Cattle Company "B" No. 1, 1,980 feet from the north line and the west line of Sec. 33, Blk. 62, Public School Lands, Culberson County, Texas (10 miles south of the south boundary of the area). Derrick floor elevation: 5,060 feet. Total depth: 5,417 feet.

PLATE II



INDEX MAP
CULBERSON, REEVES & JEFF DAVIS COUNTIES
TEXAS
0 2 4 6 8 miles
1951
CULBERSON
COUNTY
REEVES
COUNTY
JEFF DAVIS
COUNTY
DELAWARE
KENT
CHERRY
PORTERVILLE
RUSTLER SPRING
MAVERICK
TWO MILL
RUSTLER
ANTELOPE
PAINTHORSE
HARRAL
DILLAHUNTY
CHINA
TOYAH FIELD
BURCHARD
BARSTOW
SEVEN HEART
SALT DRAW
NEVILL
TINNIN
TOYAH LAKE
GENTRY
FOSTER
KENT DRAW
SAN MARTINE
GOZAR
BEACH
WILDHORSE
PLATEAU
BORACHO
HURD DRAW
KENT STATION
GOMEZ PEAK
CASEY
LOBO
WYLIE
MICHIGAN
BORACHO PEAK
HORSE CAMP
ROCKHOUSE
NEWMAN
MADERA
HOGEYE
PECOS
Salt Lake
SIERRA DIABLO
WYLIE MOUNTAINS
VAN HORN
T&P RR
Boracho
Kent
Toyah
Saragosa
Balmorhea
Mosquito Lake
Sand Lake
Alkaline Marsh
Orla
Chispa
Wendell
DAVIS MOUNTAINS
104°00'
104°30'
105°00'
103°30'
31°45'
31°30'
31°15'
31°00'
30°45'
N
S
E
W

CAMBRIAN AND ORDOVICIAN SYSTEMS

Bliss sandstone.-Only one well in the surrounding area, Humble's Reynolds No. 1, has penetrated deep enough to reach the Bliss formation. The well was bottomed in the Bliss; the bottom 77 feet was drilled in coarse-grained, white-to-yellow, partly dolomitic sandstone.

The age of the formation is still in dispute but it is generally agreed that the Bliss is the oldest marine Paleozoic formation in the region. In the El Paso and southwestern New Mexico area there is good evidence that the Bliss sandstone is upper Cambrian in age (Kelley, 1951, p. 2203). P. B. King announced (1940, p. 154) that certain fossils found in the Bliss formation of the Van Horn region were examined by Bridge, Ulrich, Kirk, and Resser and found to be lower Ordovician in age. In 1948 Cloud and Barnes (p. 66) stated in their Ellenburger report that Ordovician fossils were found only in the upper 8 feet of the Bliss sandstone of the Beach Mountains. They also added that the age of the Bliss at El Paso was not known but by analogy with the Beach Mountain section at Van Horn it might be considered lowest Ordovician until further information was available. The evidence at hand would indicate that if the Cambrian is present it must be represented only by the lower part of the Bliss sandstone. A recent article (McKee, 1951, Pl. I) strengthens the argument for the presence of Cambrian rocks in western Texas. His isopach map of the Cambrian shows a high area that extends from east-central Arizona into New Mexico. Cambrian rocks thicken southward from this high and, if extrapolated, should continue to thicken into Trans-Pecos Texas.

Lower Ordovician Series

El Paso limestone.-Humble's Reynolds No. 1, in the Apache Mountains, penetrated 930 feet of the El Paso or Ellenburger formation (the two names are synonymous in west Texas). Huffington (1951, p. 49) describes the formation as a "cream-to-tan, slightly cherty, crystalline dolomite" with some sand in the bottom 110 feet. About 20 miles north-northwest of the area, Gulf's Grisham No. 1 penetrated 190 feet into the formation, revealing a somewhat similar lithology. The El Paso is separated from the underlying Bliss sandstone by a disconformity, at least locally (King, 1940, p. 153).

Middle Ordovician Series

Simpson formation.-Gulf's Grisham No. 1 penetrated 215 feet of dark gray and brown shaly dolomite and limestone interbedded with two sandstone beds. A Simpson fauna occurs in the limestone (Upson, 1951, p. 51). Ten miles to the east, in Gulf and Grisham Hunter No. 1, the Simpson is 525 feet thick. By interpolation, the thickness of the formation under the Painthorse quadrangle would be approximately 350 feet. This thinning to the west is due to truncation by the overlying Montoya formation. In Humble's Reynolds No. 1 the Montoya and younger beds are removed by pre-Permian erosion.

Upper Ordovician Series

Montoya formation.-The Montoya consists of 270-350 feet of brown medium-grained dolomite, resting with angular unconformity on the Simpson. The identification of the Upper Ordovician in Gulf's Grisham No. 1 by Upson (1951) is based on lithology and stratigraphic position only. The identification of 350 feet of Montoya from Gulf and Grisham Hunter No. 1 is based on the interpretation of electric and radioactive logs only, since no lithologic log is available to the writer for those beds below the Fusselman.

SILURIAN AND DEVONIAN SYSTEMS

Hunton group.-The Hunton group of this thesis lies below the Woodford black shale and above the Montoya dolomite. This group consists of approximately 1,000 feet of limestone and dolomite. Gulf's Grisham No. 1 penetrated 980 feet of "Silurian and/or Devonian" described as follows (Upson, 1951): 350 feet of light gray and brown medium-grained dolomite, the upper 100 feet very porous; 165 feet of brown fine-grained limestone with some chert, shaly and slightly sandy toward the base; and 465 feet of light gray to white, coarse-grained dolomite, the upper portion of which is cherty.

The name Hunton, though disapproved by many west-Texas geologists, is a useful term for the complicated Silurian-Devonian section of that area. The section can be divided into lithologic units in some areas but, as yet, these have not been correlated with the outcrop. The basal formation of the group is the Middle Silurian Fusselman limestone, 670 feet of which have been logged in Gulf and Grisham Hunter No. 1 (Renaud, 1950, p. 32). According to that same log the top of the Silurian is 100 feet above the Fusselman at the base of a sandstone, which thus would be the basal formation of the Devonian system.

Woodford shale.-In west Texas the Woodford has for years been considered as Mississippian in age, mainly on the basis of an unconformity at its base. Ellison (1950, pp. 12-14) presented evidence which would place the Woodford of the Central Basin Platform in the Upper Devonian.

Gulf's Grisham No. 1 penetrated 365 feet of dark, non-calcareous carbonaceous shale of the Woodford formation, according to Upson's interpretation (1951, p. 51). Continental Oil Company's geologists (F. L. Stead, 1952, oral communication) have reported only 150 feet of Woodford from this same well. Continental's interpetations come closer to agreeing with the 100 feet reported from the Gulf and Grisham Hunter No. 1. It is possible that the Woodford has appeared thicker because of faulting. S. P. Ellison (1952, oral communication) stated that approximately 300 feet of black shale had been reported from the Hueco Mountains (east of El Paso) and that this would probably represent a maximum for the Painthorse area also. The nature of the contacts with younger and older beds in this area is not known, but unconformities both at the base and top are common in many parts of Texas.

MISSISSIPPIAN SYSTEM

Mississippian limestone and shale.-Overlying the Woodford, in the Gulf and Grisham Hunter No. 1, is 160 feet of shale which has been placed in the Mississippian system primarily because of its stratigraphic position (Renaud, 1950, p. 35). Gulf's Grisham No. 1 revealed 270 feet of limestone overlying the Woodford. This limestone is probably the "Mississippian lime" although Upson (1951, p. 51) questionably placed it in the Pennsylvanian.

PENNSYLVANIAN SYSTEM

Pennsylvanian shale.-The Pennsylvanian system is represented in Gulf and Grisham Hunter No. 1 by approximately 435 feet of calcareous shale with some sandstone at different levels. The presence of any Pennsylvanian rocks in Gulf's Grisham No. 1 is doubtful. Upson (1951, p. 51) indicated the presence of 188 feet of "dark gray calcareous shale" between 3,732-3,970 feet which might be Pennsylvanian. Continental Oil Company's geologists (F. L. Stead, 1952, oral communication) have interpreted the same section as

Permian resting directly on Mississippian. Whatever the ultimate decision, it is clear that the Pennsylvanian strata had been truncated by considerable erosion prior to the deposition of Permian sediments. The thickness of these strata in the Painthorse area should approximate 200 feet.

PERMIAN SYSTEM

Wolfcamp Series

The Wolfcamp series is 900-1,000 feet thick in the Painthorse area. The upper half is primarily dark shaly limestone with some black chert while the lower half is principally dark, slightly calcareous shale with a thin fine conglomerate at the base (Upson, 1951).

The two diagnostic fusulinid genera are *Paraschwagerina* and *Pseudoschwagerina* which are confined exclusively to the Wolfcamp series.

The Wolfcamp is represented by the Hueco limestone in the Hueco Mountains to the west-northwest, and there is a tendency to use that name in the Painthorse area even though the composition is different.

In the Glass Mountains an unconformity separates the Wolfcamp from the overlying Leonard series. The presence of such an unconformity in the Painthorse area cannot be determined from the few data available. It appears likely that the unconformity is restricted to the marginal areas and that sedimentation was relatively continuous in the basin itself.

Leonard Series

Bone Spring limestone.-The Bone Spring formation is comprised chiefly of 2,000-2,200 feet of dark brown shaly limestone which thickens basinward to more than the 2,575 feet reported from Gulf and Grisham Hunter No. 1.

Although both the Wolfcamp and Leonard series contain many facies, each series is referred to a single formation. The contrast between facies in the overlying Guadalupe series is more pronounced making it useful and necessary to apply formational names to the smaller units.

Guadalupe Series (Delaware Mountain Group)

The entire Guadalupe series is represented by the Delaware Mountain group, which is subdivided into the Brushy Canyon, Cherry Canyon, and Bell Canyon formations.

Brushy Canyon formation.-The Brushy Canyon formation is represented by 1,000 feet of coarse-grained sandstone interbedded with finer-grained sandstone and an occasional limestone bed composed almost entirely of fusulinid tests. In many of these limestone beds in the Guadalupe Mountains the tests are oriented in one direction indicating current action during deposition (King, 1942, p. 578).

Cherry Canyon formation.-The oldest strata exposed in Painthorse quadrangle belong to the Cherry Canyon formation of middle Guadalupe age. The formation consists of approximately 1,100 feet of fine-grained sandstone containing limestone members.

The Manzanita, or youngest, limestone member forms the top of the Cherry Canyon formation. It consists of a brownish black (5 YR 2/1) micrograined-to-paurograined limestone containing an abundance of organic remains. King (1942, p. 581) reports several thin beds of volcanic ash from this member, although none was found by the writer in the Painthorse area. In places this ash has been altered to green chert "resembling turquoise." Separating this from the middle limestone member is approximately 200 feet of sandstone. Most of this intervening sandstone is covered by Quaternary alluvium.

The South Wells (?) limestone member, the oldest rock exposed, is restricted to a single large outcrop in the northwest corner of the area in the center of a broad, gently dipping anticline. The South Wells is a medium dark gray (N 4), micrograined-to-paurograined limestone.

The South Wells and Manzanita limestone members yielded numerous fossils. The fusulinids were most useful in differentiating the Cherry Canyon from the overlying Bell Canyon formation. The genus Parafusulina has not been found higher than a few feet above the Manzanita and in west Texas the genus Leela has not been found below the lowest beds of the Cherry Canyon formation. The presence of both of these genera in great abundance was a great aid in delineating the boundaries of the formation. Near the top of the Manzanita there are two scarp-making limestone beds composed primarily of fusulinids. These horizons or zones are mapped as "f_1" and "f_2" (Pl. I). Parafusulina is the principal fossil present. In addition to the abundant fusulinids there are many poorly preserved specimens of Pseudogastrioceras scattered throughout the Manzanita and a single thin bed containing well preserved specimens of Waagenoceras cf. W. guadalupense approximately in the middle of the member. Fragments of small brachiopods were obtained from the South Wells but no identification was possible.

Bell Canyon formation.-The Bell Canyon formation (King, 1942, p. 581) includes approximately 800 feet of fine-grained sandstone and black limestone. Of the four limestone members described by King, only the Lamar is identified in the Painthorse quadrangle. Quaternary gravels cover most of the formation and effectively prevent differentiation or correlation of the few exposures of the other members.

The sand immediately below the Lamar limestone cap is known to drillers as the "Delaware sand."

There are numerous fossiliferous localities, but the state of preservation of the specimens makes any but the broadest classification very difficult. The fauna primarily consists of gastropods and ammonoids. The Lamar limestone member, named by W. B. Lang (1935, p. 262) and referred to by drillers as the "black lime," forms the top of the Bell Canyon formation.

It forms a cuesta that extends from southwest to northeast across the quadrangle effectively dividing the area into its two main subdivisions; namely, the younger evaporites to the east, and the sandstone and limestone of the Delaware Mountain group on the west. Although Owen (1951, p. 17) measured approximately 100 feet of Lamar in Seven Heart Gap to the southwest, it is only 10 feet thick in the Painthorse area.

The upper part of the Lamar is thinly laminated and grades into the Castile formation overlying it. The Lamar-Castile contact was arbitrarily based on two sedimentary features: the chert which is present in the Lamar and the color change from the dark laminated limestone of the Lamar to the lighter laminated limestone of the Castile. There is a thin zone within the Lamar that appears to be made up of silicified foraminifera. Even though examination of thin sections disclosed no structure in the individual particles, it is possible that a too rapid replacement of a fusulinid test would destroy the structure.

No other fossils were found in the Lamar member in the Painthorse quadrangle.

Ochoa Series

Castile formation.-The Castile gypsum is the lowermost formation of the Ochoa series. It rests conformably on the Bell Canyon formation and is unconformably overlain by the Rustler formation.

Because the Castile is slumped no accurate determination of structure or thickness can be derived from the gypsum itself. Gulf and Grisham Hunter No. 1, 10 miles to the east, spudded in close to the top of the formation and penetrated 1,985 feet of it. From field computations, using width of outcrop and regional dip, the Castile appears to be less than 1,000 feet thick in Painthorse quadrangle. How much of this thinning is due to pre-Rustler erosion and how much is due to natural thinning toward the west cannot be determined since most of the evidence has been removed by post-Permian erosion. To the southwest in Seven Heart Gap, the Rustler rests directly on approximately 150 feet of basal Castile which would be a clue in favor of thinning by erosion.

From the outcrop down to depths somewhere between 400 and 700 feet below the surface, the Castile consists primarily of gypsum. Beneath this level (approximately groundwater level) the evaporite takes the form of anhydrite. The Castile is characteristically a banded gypsum, containing laminae of dark, bituminous, calcitic material that fluoresces pale yellow to pale green. These laminae are discussed in detail by Udden (1924, pp. 347-354). Around many sinkholes the gypsum has been altered to selenite, which occurs in large crystals. Many thin, dark, petroliferous limestone layers are present throughout the formation. Although the largest of these is 7 feet thick, the average thickness is less than 1 foot.

The lower 50-100 feet of the Castile, being primarily a laminated limestone instead of gypsum, has been designated the Painthorse limestone member, a tentative field name suggested by R. K. DeFord.

No fossils have been reported from the Castile though organic matter must have been nearby to provide the supply of bituminous material found in the laminae.

Rustler formation.-Approximately 150 feet of Rustler formation have been mapped in Painthorse quadrangle. The Rustler lies unconformably on the Castile which it truncates westwardly. In the Painthorse area most of the lower member of the Rustler is absent and to the southwest, in Seven Heart Gap, all the lower member is missing. Here pre-Rustler erosion has removed all but about 100 feet of the basal limestone member of the Castile.

The lower member of the Rustler consists of reworked gypsum overlain by 30-40 feet of yellowish orange (10 YR 8/3), hard, siltstone which contains the fauna described by Walter (1951). The gypsum at the very bottom is red and marks the base of the Rustler. None of the reworked gypsum and only the upper portion of the siltstone is present in the Painthorse quadrangle. The middle member is a hard yellowish gray (5 Y 4/1), massively bedded, micrograined-to-paurograined, brecciated, pitted, dolomitic, unfossiliferous limestone that is gypsiferous near the base. The upper member is a dolomitic limestone somewhat similar to the middle member, but, according to Travis (1951, p. 32), it contains more calcite and less gypsum. Hughston (1950, p. 17) reported the presence of a local unconformity between the upper and middle members.

Pierce Canyon redbeds.-In the Painthorse quadrangle the Pierce Canyon formation is a thinly bedded, hard, pale reddish brown (10 R 4/3) siltstone with grayish orange pink (5 YR 8/1) spots ranging in size from 0.01 inches to 0.12 inches. A sedimentary analysis by G. L. Hutchinson (1952, oral communication) disclosed the presence of mica flakes, heavy minerals, some gypsum, and sand. The quartz grains are clear, angular, and moderately well sorted.

No fossils have been reported from the Pierce Canyon redbeds.

CRETACEOUS SYSTEM

Comanche Series

Cox sandstone.-The name Cox, as used in this thesis, refers to the "basal sand" and the "Boracho sandstone" of other theses in the immediate area. The Cox sandstone in the Painthorse quadrangle consists of two parts separated by a layer of sandy marl. The lower part may represent the Boracho sandstone tongue of the Cox; the upper part, the China sandstone tongue (DeFord, 1951).

Previous determinations for this sandstone have ranged from Trinity to Washita in age. In the Painthorse quadrangle fossils of Washita age have been found in the thin bed of marl. No evidence was found which would suggest an unconformity between the marl and the lower part of the Cox so it would not be improper to assume that the age of this part of the Cox, in this vicinity, is also Washita, or at most is no older than upper Fredericksburg.

The Cox is predominately a pale yellowish brown (10 Y 6/2) to reddish brown (10 R 5/4), medium to coarse grained, well cemented sandstone. At its base there is a fine-grained quartz conglomerate containing many pebbles of white and black chert.

Immediately above the lower sandstone member is the bed of sandy marl 2 feet thick containing many fossils. Although no diagnostic species were identified, the general appearance of the fauna, according to Dr. Keith Young (1951, oral communication), suggested a Washita age. Above this marl is a continuation of coarse sandstone that is similar to that beneath the marl; roughly 30-50 feet of the upper sandstone member is present in the Painthorse quadrangle and a greater thickness to the east in Harral quadrangle, where the top of the section may be seen. The outcrop is restricted to the syncline in the southeast corner of the area and cannot be traced farther south where a more accurate correlation might be made with better known sections of Cretaceous rocks. On Plate I the lower member is mapped as "Cox" overlain by "marl and sandstone of Washita age."

The basal 2 feet of the section is a pale yellowish brown (10 Y 6/2) marl which contains the fauna. The color of the sandstone ranges from a pale yellowish brown (10 Y 6/2) to a reddish brown (10 R 5/4). The reddish brown color is more conspicuous in the lower portion of the section.

GU CONGLOMERATE

The initial letters of the words gravel and undifferentiated were used to form the map symbols GU and UG to designate the two conglomerates of undetermined age (Pl. I). The GU conglomerate has been found in only one locality in the area (SW 1/4 NW 1/4 of Sec. 14, Blk. 93, PSL) where it is closely associated with basal Cretaceous sandstone in a sinkhole deposit. The GU conglomerate is composed of well rounded, spherical dolomite boulders with some well rounded pink chert pebbles containing fusulinids. These fusulinids resemble *Parafusulina* or *Polydiexodina* though the specimens are not sufficiently well preserved to positively identify. The dolomite boulders range in diameter from 2.5 cm to 5.0 cm. Some well rounded boulders of pisolitic limestone are included in the conglomerate. Pisolites are common in the slightly-back-reef area of the Apache Mountains (DeFord, 1951, oral communication). The age of this conglomerate cannot be accurately determined. Its age is post-Castile and pre-Gozar.

UG CONGLOMERATE

The UG conglomerate is found in only a single locality of the northeast corner of the area (locality No. 36, Pl. I) where it caps a hill of basal Castile limestone.

The UG is a very coarse, well-cemented conglomerate consisting of angular fragments of siltstone and sandstone (apparently from rocks of Guadalupe age) and some well-rounded limestone boulders. Many of these limestone boulders are fragments of the Castile formation. The matrix of the conglomerate is sandstone, the color of which ranges from a moderate yellowish brown (10 YR 6/2) to a pale light brown (5 YR 6/2). Its age is uncertain. It is younger than the Castile fragments it contains and is probably older than the Gozar or Neville formations because it is topographically higher than either of these. The presence of Castile fragments precludes the possibility of a distant source and the rounded appearance of some of the other particles would discredit the argument for its being a slump breccia. The general aspect of the conglomerate suggests a stream deposit of pre-Gozar age.

QUATERNARY SYSTEM

The following formations are taken from DeFord's (1951) "precursory classification." Only those exposed in Painthorse quadrangle are included.

Tentative name	Symbol	Description
Calamity formation	Qc	Alluvium, gray, organic; present in stream channels.
Neville formation	Qn	Older, orange, fill; contains caliche pebbles.
Gozar formation	Qgy, Qgv	Well cemented in places; in exposures surrounded by Neville or benches above Neville. (Qgv is gravel facies; Qgy is the gypsite facies.)
Ninemile gravel (oldest)	Qnm	Benches above Gozar; forming divides between draws.

Ninemile gravel.-In Painthorse quadrangle the Ninemile terrace gravel occurs at two localities relatively high on the flank of the Delaware Mountains. It represents a remnant of a high terrace level, most of which had been removed by pre-Gozar and/or pre-Neville erosion.

The gravel consists of well-rounded, unconsolidated fragments of limestone averaging 4 inches in length and varying from a moderate olive brown (5 Y 4/2) to a dusky yellow (5 Y 6/2).

Gozar formation.-The Gozar, the next youngest formation, consists of two separate and distinct facies. East of the Castile-Bell Canyon contact, where the bedrock is gypsum, the Gozar is found in terraces of earthy, white gypsite. Because the Castile is, in many localities, covered with its own weathered mantle of gypsite this facies is very difficult to map. West of the Castile-Bell Canyon contact the Gozar is a coarse gravel of well-rounded dark limestone fragments identical with those of the Ninemile formation. These fragments contain abundant specimens of Parafusulina, and probably were derived (originally) from the Brushy Canyon or Cherry Canyon outcrops in the Delaware Mountains. These fragments seem to be reworked fragments of the Ninemile formation.

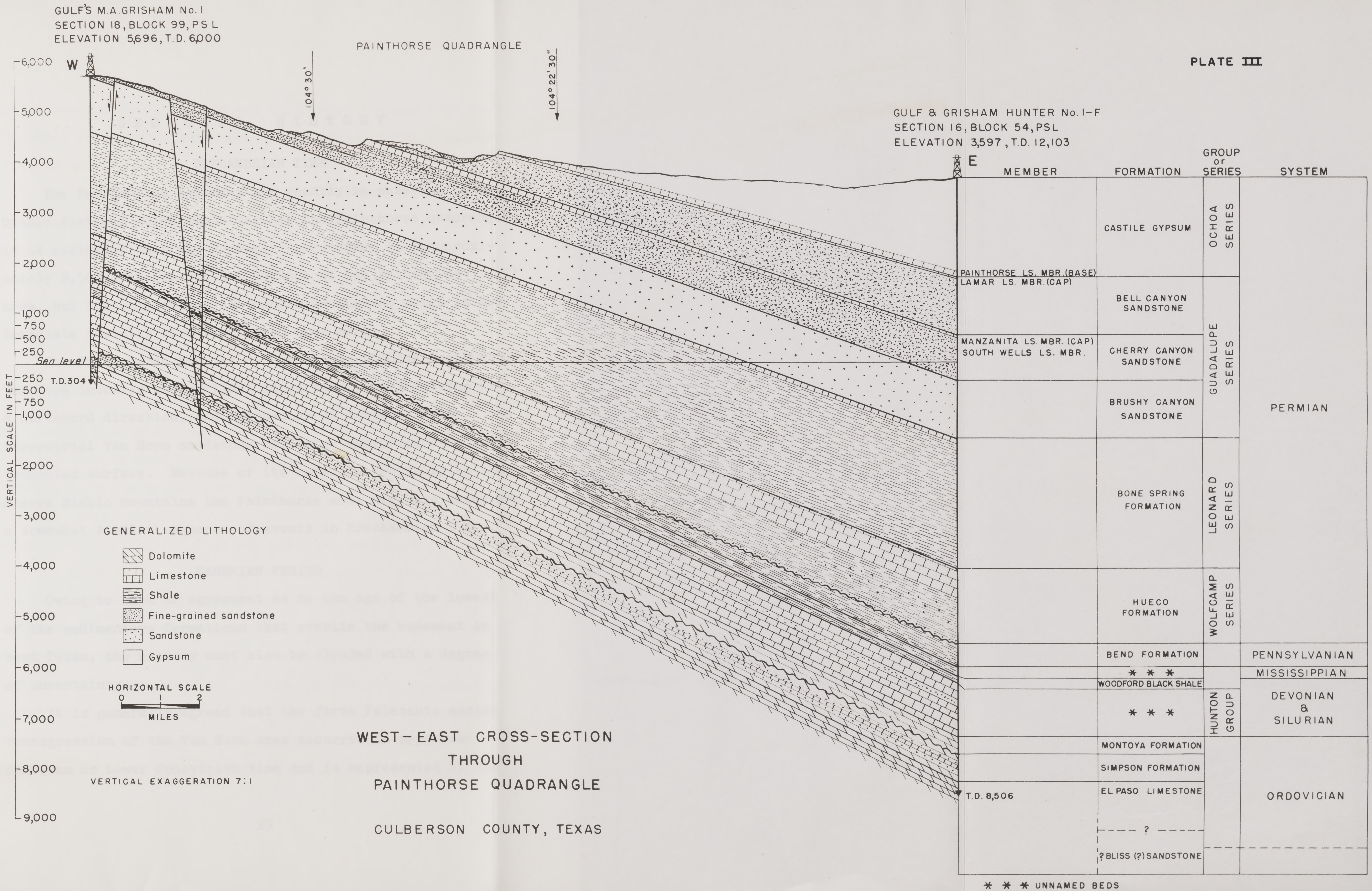
Neville formation.-The Neville formation in the Painthorse area is primarily a grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6) gypsiferous silt and sand. West of the Castile outcrop there is little gypsum in the formation. In the vicinity of Painthorse dam the Neville contains a coarse conglomerate of sandstone and siltstone slabs a few inches thick that range in length from a few inches to several feet. Two thin caliche layers are visible in the conglomerate at this locality.

Pre-Neville erosion, in many places, cut deeply into the older rocks forming troughs in which 50 feet or more of Neville alluvium has been accumulated.

No fossils were collected from this formation although Travis (1951, p. 48) reports a Wisconsin age fauna from the Neville of Harral quadrangle, contiguous with the Painthorse area on the east.

Calamity formation.-The Calamity is the youngest formation mapped in the quadrangle. It is a light to dark gray alluvium that forms a soil on which grows the dense vegetation of the stream channels. Normally this formation is only a few inches to a few feet thick; locally it may be several feet thick.

PLATE III



WEST-EAST CROSS-SECTION
THROUGH
PAINTHORSE QUADRANGLE

CULBERSON COUNTY, TEXAS

G E O L O G I C   H I S T O R Y

PRECAMBRIAN TIME

The Precambrian basement may readily be observed in the Diablo Plateau, 30-40 miles west of the Painthorse quadrangle. It is estimated that the Precambrian basement lies approximately 8,500 feet beneath the surface of the Painthorse area, but its composition is unknown because no wells in the immediate vicinity have penetrated that deep.

The Precambrian history of the Sierra Diablos north of Van Horn involves geosynclinal deposition, overthrusting in a northward direction, and intrusions of diabasic sills. The terrestrial Van Horn sandstone was later deposited over this truncated surface. Because of its relative proximity to the Sierra Diablo Mountains the Painthorse area may have undergone a somewhat similar sequence of events in Precambrian time.

CAMBRIAN PERIOD

Owing to lack of agreement as to the age of the lowest of the sedimentary formations that overlie the basement in west Texas, the history must also be clouded with a degree of uncertainty.

It is generally agreed that the first Paleozoic marine transgression of the Van Horn area occurred in uppermost Cambrian or Lower Ordovician time and is represented by the

Bliss sandstone. The Bliss sea must have extended from the Marathon region northward across the Painthorse area to central Arizona and New Mexico.

The Bliss sandstone is not a geosynclinal deposit for no geosyncline existed in the Paleozoic history of west Texas until the Pennsylvanian development of the Llanoria trough. The Bliss sea was the first of many epicontinental seas which were to transgress the Painthorse area from Cambrian to Permian times.

ORDOVICIAN PERIOD

The transition from Cambrian to Lower Ordovician is not noticeable in the sedimentary record of the Van Horn region. The boundary between the two periods is presumably located somewhere in the Bliss formation. Ordovician deposition, for the most part, appears to have taken place in relatively quiet water sufficiently far from any elevated land mass to account for the scarcity of clastic silicate material in most of the section. The numerous unconformities in the section and the occasional appearance of sandstone indicate an unstable shelf during this period. The three epochs of the Ordovician period were terminated by uplifts. During the interval preceding the invasion of the Montoya sea the area was tilted so that the Montoya rests with angular unconformity on the truncated Simpson surface. The Ordovician period was brought to a close by regional uplift which was to prevent the transgression of another sea until Middle Silurian time.

SILURIAN PERIOD

The Silurian and all the Devonian rocks except the Woodford formation are lumped into the Hunton group, a unit which is generally not separated into distinct systems in west Texas. An arbitrary division has been selected approximately 95 feet above the top of the Fusselman (Renaud, 1950, p. 35). The Silurian would then be represented only by carbonate deposits which are not unlike those deposited during the Ordovician. The Painthorse area was covered by another of the shallow epicontinental seas which covered Trans-Pecos Texas throughout most of the Paleozoic era.

DEVONIAN PERIOD

The Devonian epeiric sea that transgressed the eroded Silurian surface deposited a basal sandstone across the area which was followed by a gradual deepening of the waters and the deposition of cherty limestone. From a study of other areas a slight discordance but large hiatus might exist at the top of this cherty limestone, separating it from the overlying Woodford black shale.

The environment of deposition must have changed considerably to account for the succession of black shale beds which were deposited in Woodford time. The nature of the

Woodford shale is not well known in Trans-Pecos Texas though black shale of similar stratigraphic position is reported from isolated localities in western Texas and southern New Mexico.

The Painthorse area was undoubtedly a part of this restricted, stagnant, marine environment into which fine mud was carried from low-lying borderlands.

MISSISSIPPIAN PERIOD

Mississippian rocks indicate a return to the pre-Woodford conditions of an unrestricted marine shelf-type environment in which carbonate rock and siltstone and shale predominate.

PENNSYLVANIAN PERIOD

Painthorse quadrangle is on the northern flank of a late Pennsylvanian high from which most of the normally-thick Pennsylvanian deposits have been removed by pre-Permian erosion. Only shale belonging to one epoch, the Bend, is present in the area.

To the south in the Marathon region the Llanoria geosyncline began to develop and great thicknesses of clastic silicate sediments were deposited. The Painthorse area was sufficiently far north to remain relatively unaffected by this downwarping.

PERMIAN PERIOD

The late Pennsylvanian orogeny folded and faulted the strata in the Llanoria geosyncline to the south. In the foreland area to the north this movement took the form of gentle uplifts and folds. The erosion which followed cut deeply into these foreland features and, in places, completely removed all sedimentary rocks. This orogeny marked the transition of the Painthorse area from a shelf-type depositional province to an intracratonic basin, which became more restricted as the Permian period progressed. The Permian history of the Delaware Basin is fully discussed by King (1942, pp. 711-763). The interpretation which follows is an attempt to isolate that portion of the Permian history which applies to the Painthorse area and insert any new ideas which may have evolved from the writer's field work, particularly on the upper part of the Permian.

Wolfcamp Epoch

The deposits of the Wolfcamp sea, which transgressed west Texas and southern New Mexico, are characterized by dark shales and limestones. Coarser sand from the marginal lands to the south and southwest occasionally was carried far enough basinward to be deposited as thin sandstone tongues or lenses in the predominately shale and carbonate section. Deposition appeared to have kept pace with subsidence for the depth of the water was not great. The Wolfcamp epoch came to a close in the area with no known sedimentary break.

Leonard Epoch

The end of Wolfcamp time was marked by a mild orogeny to the southeast in the Glass Mountains (King, 1942, p. 737) but in the basin the rocks of lower Leonard age are very similar to those of the underlying Wolfcamp.

In late Leonard time the marginal shelf areas outside the basin were covered with sand probably originating from uplifts in the Llano and Marathon areas (King, 1942). Following this came a readvance of the sea in which widespread limestone deposits were laid down over the sandstone on the shelf area. Basinward the limestone grades into black shale and black limestone similar to those of the lower Leonard. The deposits in the Painthorse area are predominately black shale, indicating that the area was sufficiently far in the basin to miss both the sandstone and limestone that characterize the marginal area. According to King (1942, p. 620) the black limestone and shale of Leonard age were quiet-water deposits.

Guadalupe Epoch

Brushy Canyon time.-The change from the black shale of the Bone Spring formation to the sandstone of the Delaware Mountain group is rather abrupt. The sandstone of the Brushy Canyon is confined to the basin suggesting that the shelves beyond the basin were emergent (King, 1942, p. 749).

The water in Brushy Canyon time was shallow and subject to agitation as the orientation of fusulinid tests and coarseness of sand grains would indicate. The basin must have been subsiding at a rather uniform rate to allow some 1,000 feet of sandstone to accumulate to the almost complete exclusion of other types of sedimentary material.

Cherry Canyon time.-The middle Guadalupian subepoch was marked in the sedimentary record by a gradual change from the coarse sandstone of the Brushy Canyon to the finer-grained clastic silicate material and dark organic limestone of the Cherry Canyon. It was during this time that a barrier reef began to grow around the fringes of the basin, effectively halting the basinward spread of the coarser sediments from the surrounding lands. This reef continued to grow through the rest of the Guadalupe epoch. Today this reef is presumably downfaulted in the Salt Flat graben to the west of the Delaware Mountains. The southern continuation of the reef forms the Apache Mountains 10 miles south of the Painthorse area.

The Delaware Basin continued to subside during Cherry Canyon time but sedimentation could not keep pace with subsidence and the Painthorse area began to be covered by deep water. The structure of the reef masses also indicates that they were high above equivalent beds in the basin (King, 1942, p. 621).

Bell Canyon time.-The transition from Cherry Canyon to Bell Canyon time was marked only by the evolution of the organisms that lived in the seas. The rocks of the Bell Canyon are very similar in lithology to those of the Cherry Canyon.

Inasmuch as both the Capitan reef and its precursor of Cherry Canyon age encircled the Delaware Basin and grew to greater heights above the basin as time went on, it is difficult for geologists to explain the source of the Bell Canyon and Cherry Canyon sandstone. King (1942, pp. 749, 753) discussed two possibilities. The argument for the source lying to the north postulates that only the finer sediments from the marginal land masses would filter through the reef while the coarser sediments would be trapped in the back-reef lagoons. The other possibility would be transportation by marine currents through the Hovey channel from the south. The Marathon folded belt could have been the source of these Delaware Mountain sandstones. Adams (1936, p. 789) introduced the third possibility, suggesting eolian transportation. It is the writer's opinion that all of these methods probably contributed to the two thousand feet of sediments deposited during these two subepochs.

King (1942, p. 757) reported the presence of thin layers of bentonite and volcanic ash in beds of middle and upper Guadalupe age. This volcanic activity probably took place to the south in the Llanoria region.

The Guadalupe epoch was brought to a close by the sudden appearance of the evaporites of the Castile formation. The entrance to the Delaware Basin must have become constricted rather suddenly to cause such an abrupt change in sedimentary conditions. It is believed that the accumulated brine in the Castile sea caused the death of the reef.

Ochoa Epoch

Castile time.-P. B. King (1942, p. 759) postulated that a lowering of the sea-level would have caused the submarine ridge of the Hovey anticline to lie nearer the surface and reduce the flow of water into the Delaware Basin. Reef growth across the mouth of the channel has been suggested as another possibility in the restriction of the basin.

R. H. King (1947, pp. 470-477) introduced a plausible theory to explain the great thickness of anhydrite deposited in the basin. It is a modification of Ochsenius' "bar theory" and requires the return to the sea of the heavier concentrated brine along the bottom of the channel or through a porous medium (bar or reef) while a new suply of (lighter) normal marine water flows into the basin closer to the surface of the channel. This way there would be a continuous supply of normal marine water to replace that lost by evaporation and still not allow the water to exceed the salinity in which anhydrite will be directly precipitated. This explanation, as do most others, requires a fine balance of conditions over a long period of time. The limestone laminae deposited throughout the Castile indicate the slight variations which must have taken place from time to time, either in the volume of inflow or rate of evaporation.

Overlying the Castile further out in the basin is the Salado formation, composed primarily of salt with some anhydrite and potash. The Salado sea quite probably did not extend westward far enough to include the Painthorse area because the formation passes into a near-shore facies near the Pecos River, some 50 miles to the east (Kronlein, 1939, pp. 1686-1688). The Castile evaporites must have, to a great extent, filled the basin so that the Salado was probably laid down in shallow water (Adams, 1936, p. 789).

Rustler time.-The deposition of the Rustler formation followed the uplift and erosion of the Salado deposits. Pre-Rustler erosion was of sufficient duration to remove a considerable thickness of Castile anhydrite (though the amount removed is not clearly indicated in the Painthorse area). In Seven Heart Gap, some 8 miles to the southwest, the middle or upper Rustler rests on basal Castile indicating the removal, in that area, of at least 1,000 feet of the Castile formation.

The Rustler sea in which dolomitic limestone and siltstone were deposited indicate a return to the more normal marine conditions as evidenced by the appearance of a molluscan fauna with some brachiopods and crinoids (Walter, 1951). Rustler time came to a close with the retreat of the sea from the area.

Pierce Canyon time.-Following the retreat of the Rustler sea the fine-grained silt of the Pierce Canyon formation was spread over the area. According to H. G. Damon (oral communication, 1952) the grain size and sorting of the sediments are typical of a floodplain deposit, yet the widespread occurrence and constant thickness of these redbeds preclude fluvial deposition.

CRETACEOUS PERIOD

Comanche Epoch

<u>Fredericksburg (?) time</u>.-If the Fredericksburg is represented by any deposits in Painthorse quadrangle it would be in the lower part of the Cox sandstone. The Lower Cretaceous sea transgressed the area from the south and southwest. A few miles to the south the basal sandstone is definitely Fredericksburg in age but in the Painthorse area it lies within a few feet of Washita beds. It, then, is apparent that the Lower Cretaceous sea transgressed the area in latest Fredericksburg or in Washita time and that the area was close to the shore during this time.

Whatever the age of the sandstone it is evident that it was deposited over an uneven surface of Rustler, and in spots, Pierce Canyon redbeds. The redbeds must have been almost completely removed prior to Cretaceous deposition. Evidence for this lies in the fact that in many sinkhole deposits where Rustler and Cretaceous rocks are closely associated the Pierce Canyon redbeds are noticeably absent. In others there are at least fragments of the red siltstone present.

Washita time.-Washita time began, at the latest, with the deposition of the marl containing the invertebrate fauna mentioned earlier. In the Painthorse quadrangle the only sediments deposited during this time formed the marl and the overlying sandstone now exposed in the syncline.

The area is on the shelf of the Cretaceous geosyncline which was then developing to the southwest.

Gulf Epoch

Travis (1951, pp. 41-43) reported the presence of Gulf deposits in Harral quadrangle. Sinkhole material was found which contained foraminifera of Austin or Taylor age. The presence of pelagic forms in this assemblage makes it probable that the Austin or Taylor sea extended considerably farther north than the Painthorse area.

A regional uplift forced the recession of the sea from the area for the last time and brought Cretaceous deposition to a close.

TERTIARY PERIOD

Although the area did not see a marine transgression during the Tertiary, deposition of another sort was to take place. Far to the south, in the Big Bend region of

Texas, in uppermost Eocene or lower Oligocene time (J. A. Wilson, 1952, oral communication) igneous rocks began to be extruded. As the top of the very thick section of flows and tuffs has not been seen, no precise information is available on the duration of the volcanism. There is no evidence that the flows reached the Painthorse area but the presence of an occasional well rounded igneous boulder from the south affords a clue to the history of the area. Prior to the uplift of the Apache Mountains there must have been a drainage system flowing northward from the Davis Mountains across Painthorse quadrangle. Indirect evidence for this is present in Hurd Draw which cuts through the reef mass of the Apache Mountains. This draw must have been superimposed on the Permian limestone by erosion of a Cretaceous cover. The Davis Mountains volcanic rocks were extruded onto this surface. Following this volcanic activity the region began to be uplifted and tilted to the east. It was at this time that the Delaware Mountains were formed and erosion began which was to expose the Apache reef roughly in the form it exhibits today.

The faulting which accompanied the formation of the Delaware Mountains followed a general NW-SE trend.

There are two systems of faults in the Painthorse area. The smaller (and what appears to be the older) system of faults follows this trend. The more extensive system follows a S 80° W trend.

The writer believes that faulting occurred at two different times, the S 80° W trend being the youngest. The younger age of this trend is based on two observations: the calcite filling on the NW-SE faults is badly weathered while the filling on the S 80° W faults is relatively fresh looking, and, more conclusively, the NW-SE system is slightly displaced by the S 80° W systems.

There are no Tertiary deposits in the area. The Tertiary was a period of erosion which saw the elevation of the Delaware and Apache mountains and the beginning of extensive leaching of the Ochoa evaporites. The presence of sinkhole material along the axes of the stream channels on the Castile outcrop indicates the present channels probably were initiated by subsurface solution. The syncline in the southeast corner of the area might have been the result of solution on a large scale.

QUATERNARY PERIOD

The oldest post-Cretaceous geomorphic level in the immediate vicinity is the Gypsum Plain (Richardson, 1904). Remnants of this plain are present in Harral quadrangle, but apparently all traces of it have been removed from the Painthorse area.

Ninemile time.-The Ninemile terrace that marks the next younger level is comprised of limestone boulders from the Delaware Mountains to the west. Prior to Ninemile deposition Cottonwood and Painthorse Draws must have been formed, although they probably were widened and deepened during younger intervals of erosion.

Gozar time.-There was an erosional interval after Ninemile deposition and prior to Gozar time. Most of the older and higher terrace was removed, reworked, and redeposited as the Gozar formation. Gypsite terraces are located at about the same geomorphic level and so are correlated with the gravel facies.

Neville time.-There was an interval of quite deep erosion prior to the beginning of Neville deposition. In some localities narrow gorges, deeper than they are wide, are filled with Neville alluvium. According to Albritton and Bryan (1939, p. 1433) the Neville was deposited by shallow streams under semiarid conditions. Deposition proceeded slowly enough so that plant growth in the valley flats was not prevented. The vegetation was necessary to support the large herbivorous animals that roamed the area. In the area studied by Albritton and Bryan the Neville is limited to the valley flats. An anomalous situation exists in the Painthorse area where the Neville is found both in the valleys and high on Castile and Delaware Mountain outcrops. It appears, then, that the Neville was primarily a soil which formed on bedrock at these higher outcrops and was washed down by rains and deposited as alluvium in the valleys. It is present on hills today only because erosion was insufficiently strong to remove it completely.

Calamity time.-Little is known about the Calamity formation in the Painthorse quadrangle. The few inches of this deposit in the area are difficult to study. It has a well developed soil profile and supports abundant vegetation which was an aid to mapping it but not much help in deducing its history.

E C O N O M I C   A S P E C T S   O F
G E O L O G I C   H I S T O R Y

OIL AND GAS

Several events in the geologic history of Painthorse quadrangle strongly suggest the presence of petroleum reservoirs in the vicinity. Ordovician, Silurian, Devonian, Pennsylvanian, and Permian rocks are present in the subsurface, all of which contain oil in other parts of west Texas. Until recently the presence of structure in the subsurface was difficult to determine because of the scarcity of deep wells. The completion (May, 1952) of a new gas well producing from a pre-Permian presumably Devonian reservoir rock, M. A. Grisham's Fee No. 1, in Sec. 10, Blk. 60, T. and P. RR. (7 1/2 miles east of the east boundary of the Painthorse quadrangle) suggests that the Pennsylvanian orogeny, which folded and faulted the Marathon region to the southeast, was sufficiently strong to cause anticlinal closures in the vicinity of the Painthorse area. The subsequent deposition of Permian strata over this folded and eroded surface helped to create or seal off the necessary traps to contain the oil and gas. The anticline in the northwest corner of the Painthorse quadrangle (Pl. I) suggests the possibility of differential settling along such a pre-Permian high since there is no evidence for post-Permian compressional folding in the area. A projection of this anticlinal trend eastward through the Painthorse quadrangle to join the structural feature now yielding gas is not unlikely.

The new well also revealed thin lenses of "relatively unconsolidated oil-stained sand" in the Wolfcamp which were too thin to be produced economically.

Tertiary faulting along a northwest-southeast trend may have created traps for oil migrating updip toward the Delaware Mountains in Oligocene or younger time. King (1949) mapped several faults of this type immediately west of the quadrangle.

WATER

The Tertiary faulting which formed the Delaware Mountains elevated sandstone beds of the Delaware Mountain group and increased their eastward dip. These beds are the most likely aquifers in the area. As a result of late Permian history all the water obtained from shallow wells in the Painthorse quadrangle is charged with $CaSO_4$ from the Castile gypsum and rendered unfit for human consumption. Fortunately cattle and sheep adapt themselves to it readily. The only "sweet water" in the immediate vicinity, other than the surface water caught in earthen tanks, is that from a spring just west of the quadrangle. Water migrating downdip from the Delaware Mountains comes to the surface along one of these Tertiary faults.

The present aridity of the region is historically determined. During the pluvial cycles of the Quaternary period there have been much wetter times, and also more arid times in some of the interpluvial epochs.

R E F E R E N C E S

ADAMS, J. E. (1936) Oil pool of open reservoir type: Bull. Amer. Assoc. Petr. Geol., vol. 20, no. 6, pp. 780-796.

_____ (1944) Upper Permian Ochoa series of Delaware Basin, west Texas and southeastern New Mexico: Bull. Amer. Assoc. Petr. Geol., vol. 28, no. 11, pp. 1596-1625.

ALBRITTON, C. C., and BRYAN, K. (1939) Quaternary stratigraphy in the Davis Mountains, Trans-Pecos Texas: Bull. Geol. Soc. Amer., vol. 50, pp. 1423-1474.

BARTON, J. M. (1945) Pre-Permian axes of maximum deposition: Bull. Amer. Assoc. Petr. Geol., vol. 29, no. 9, pp. 1336-1348.

BEEDE, J. W. (1924) Report on the oil and gas possibilities of University block 44 in Culberson County: Univ. Texas Bull. 2346, pp. 1-16.

CARTWRIGHT, L. D. (1930) Transverse section of Permian Basin, west Texas and southeastern New Mexico: Bull. Amer. Assoc. Petr. Geol., vol. 14, no. 8, pp. 969-981.

CLOUD, P. E., and BARNES, V. E. (1946) The Ellenburger group of central Texas: Univ. Texas Publ. 4621.

DeFORD, R. K. (1951) Precursory classification of Trans-Pecos formations: Univ. Texas, mimeographed, 6 pp.

ELLISON, S. P. (1950) Subsurface Woodford black shale, west Texas and southeast New Mexico: Bur. Econ. Geol., Rept. Investigations No. 7.

HUFFINGTON, R. M. (1951) Geologic section in Humble Oil and Refining Company's Reynolds Cattle Company "B" No. 1: West Texas Geol. Soc. Guidebook for 1951 Fall Field Trip, pp. 47-49.

HUGHSTON, E. W. (1950) Geology of northern half of Salt Draw quadrangle, Culberson County, Texas: Univ. Texas thesis.

KELLEY, V. C. (1951) Oolitic iron deposits of New Mexico: Bull. Amer. Assoc. Petr. Geol., vol. 35, no. 10, pp. 2199-2228.

KING, P. B. (1935) Outline of structural development of Trans-Pecos Texas: Bull. Amer. Assoc. Petr. Geol., vol. 19, no. 2, pp. 221-261.

_____ (1940) Older rocks of the Van Horn region, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 24, no. 1, pp. 143-156.

_____ (1942) Permian of west Texas and southeastern New Mexico: Bull. Amer. Assoc. Petr. Geol., vol. 26, no. 4, pp. 535-763.

_____ (1949) Regional geologic map of parts of Culberson and Hudspeth counties, Texas: U. S. Geol. Survey, Oil and Gas Investigations Preliminary Map 90.

KING, R. H. (1947) Sedimentation in Permian seas: Bull. Amer. Assoc. Petr. Geol., vol. 31, no. 3, pp. 470-477.

KRONLEIN, G. A. (1939) Salt, potash, and anhydrite in Castile formation of southeast New Mexico: Bull. Amer. Assoc. Petr. Geol., vol. 23, no. 11, pp. 1682-1692.

LANG, W. B. (1935) Upper Permian formations of Delaware Basin of Texas and New Mexico: Bull. Amer. Assoc. Petr. Geol., vol. 19, no. 2, pp. 262-270.

_____ (1937) The Permian formations of the Pecos Valley: Bull. Amer. Assoc. Petr. Geol., vol. 21, no. 7, pp. 833-898.

LEWIS, F. E. (1944) Position of the San Andreas group of west Texas and New Mexico: Bull. Amer. Assoc. Petr. Geol., vol. 25, no. 1, pp. 73-103.

McKEE, E. D. (1951) Sedimentary basins of Arizona and adjoining areas: Bull. Geol. Soc. Amer., vol. 62, no. 5, pp. 481-506.

MILLS, J. M. (1942) Rhythm of the Permian seas - a paleogeographic study: Bull. Amer. Assoc. Petr. Geol., vol. 26, no. 2, pp. 217-255.

OWEN, D. E. (1951) Geologic structure of Seven Heart Gap, Culberson County, Texas: Univ. Texas thesis.

PAGE, L. R., and ADAMS, J. E. (1940) Stratigraphy, eastern Midland Basin, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 24, no. 1, pp. 52-64.

RENAUD, C. B. (1950) Geology of China Draw area, Culberson County, Texas: Univ. Texas thesis.

RICHARDSON, G. B. (1904) Report of a reconnaissance in Trans-Pecos Texas north of the Texas and Pacific Railway: Univ. Texas Mineral Surv. No. 9 (reclassified: Bull. of The Univ. of Texas, No. 23).

_____ (1914) Geology of Van Horn area, Texas: U. S. Geol. Sur. Atlas, Folio No. 194.

UDDEN, J. A. (1924) Laminated anhydrite in Texas: Bull. Geol. Soc. Amer., vol. 35, pp. 347-354.

UPSON, M. E. (1951) Geologic section in Gulf Oil Corporation's M. A. Grisham No. 1: West Texas Geol. Soc. Guidebook for 1951 Fall Field Trip, pp. 50-51.

WALTER, J. C., Jr. (1951) Paleontology of Rustler formation, Culberson County, Texas: Univ. Texas thesis.

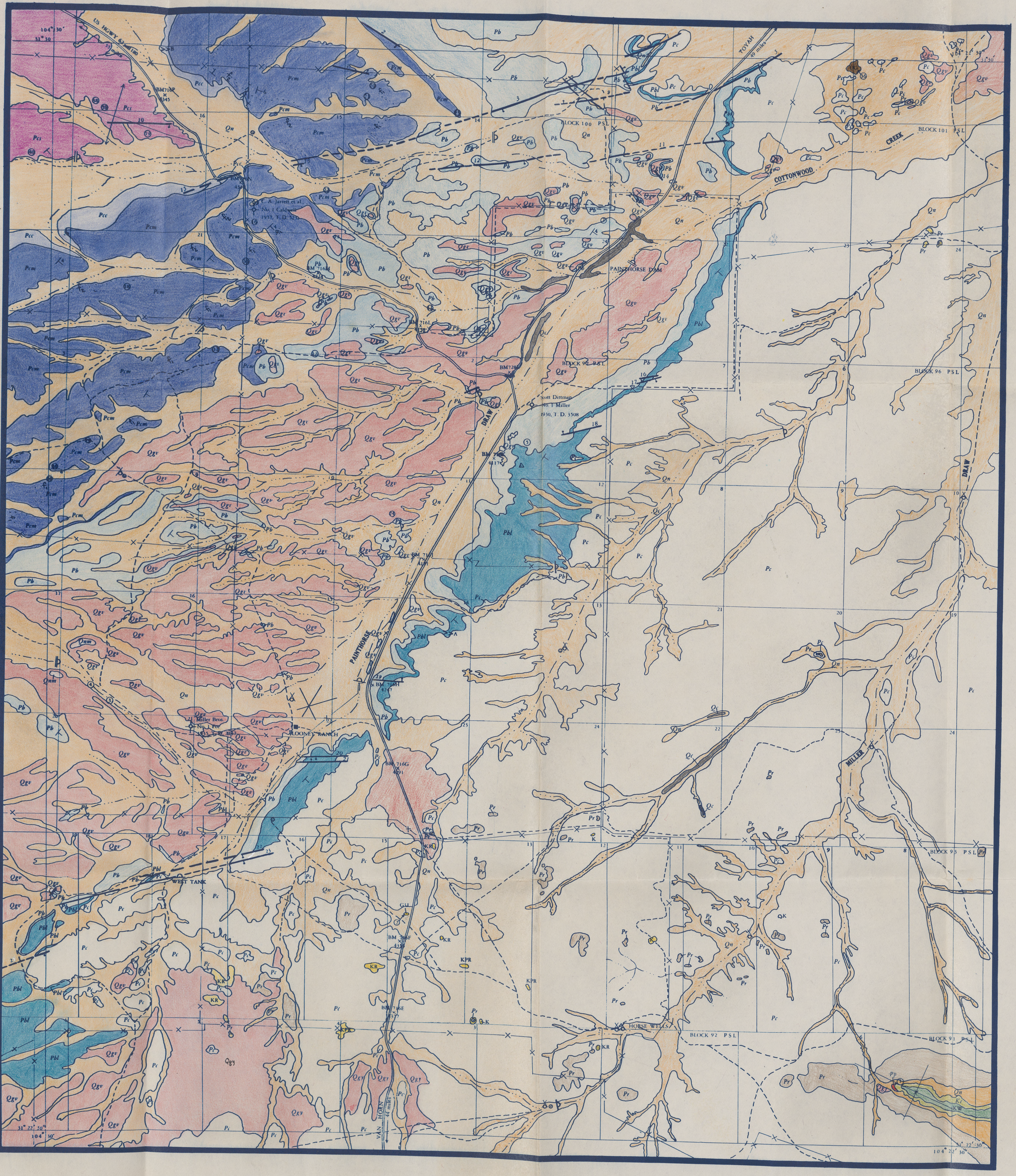


Plate I

QUATERNARY

- Qc — Calamity alluvium
- Qn — Neville alluvium
- Qgy Qgv — Gozar formation; Qgy, gypsite member; Qgv, gravel member
- Qnm — Ninemile gravel

- UG — Conglomerate, brown, age undetermined; caps hill
- GU — Conglomerate, age undetermined
- K — Cretaceous conglomeratic sandstone
- P — Pierce Canyon redbeds
- R — Rustler dolomite

(GU, K, P, R:) components of brecciated sinkhole fill

CRETACEOUS

- KW — marl & sandstone of Washita age
- Kc — Cox sandstone

PERMIAN

OCHOAN

- Pp — Pierce Canyon redbeds
- Pr — Rustler formation
- Pc — Castile formation

GUADALUPIAN

- Pbl, Pb — Bell Canyon formation, Pb; Lamar limestone member, Pbl, at top.
- Pcm, Pcc, Pcs, Pcc — Cherry Canyon formation, Pcc; Manzanita limestone member, Pcm, at top; South Wells (?) limestone member, Pcs.

anticlinal axis	county road
synclinal axis	ranch road
A — measured section A	fence
BM 716E 4377 — USC & GS benchmark No. 716E Elevation 4377 feet above sea level	3 — observed fault No. 3
USC & GS triangulation station	concealed fault
landing strip	fault trace visible through Quaternary cover
buildings	windmill
earthen tank	water-storage tank
earthen dam	dry well (oil test)
7 — fossiliferous locality No. 7	f1 — fossiliferous bed No. 1

AREAL GEOLOGY PAINTHORSE QUADRANGLE

Culberson County, Texas

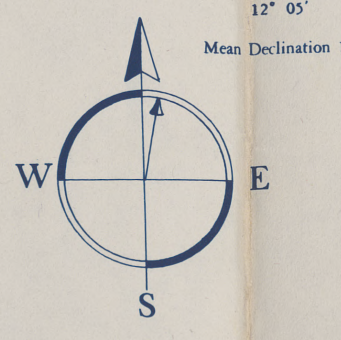
Cartography by

Asa L. Blankenship, Jr. George Sealy

Supervised by R. K. DeFord & J. A. Wilson

Department of Geology The University of Texas

FIELD WORK
SUMMER, 1951



MAP PRINTED
DECEMBER, 1951

BASE FROM EDGAR TOBIN
AERIAL MOSAIC

1 0 1 2

SCALE IN MILES

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